(11) Publication Number: Japanese Patent Publication No. 2-201904
(43) Publication Date: August 10, 1990 (Heisei 2)
(54) Title of the Invention: High Magnetic Permeability Material
(21) Application Number: Japanese Patent Application No. 1-20287
(22) Filing Date: January 30, 1989 (Heisei 1)
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Specification

1. Title of the Invention

High Magnetic Permeability Material

2. Claims

(1) A high magnetic permeability material, characterized in that a polymer deposits between ferromagnetic metal particles, the saturation magnetization is 800 G or higher, and the electrical resistivity is 180 μΩ-cm or higher.

3. Detailed Description of the Invention

[Field of Industrial Application]

The present invention relates to a high magnetic permeability material, and in particular to a high magnetic permeability material having excellent high-frequency properties and a high saturation magnetic flux density.

[Prior Art]

In recent years, electronic devices have been becoming smaller and increasingly used in high frequency regions. Therefore, a high magnetic permeability material has been required for devices that operate in higher frequency regions. High magnetic permeability materials include those made of a ferromagnetic metal and those made of an oxide magnetic material.

[Problem to be Solved by the Invention]

High magnetic permeability materials made of a ferromagnetic metal have a small electrical resistance, and therefore the eddy current loss becomes high in high frequency regions, and thus there is a problem, such that the high frequency properties are poor.

In addition, magnetic materials having little eddy

current loss in high frequency regions include oxides, such as ferrite, but such materials have a defect, such that the saturation magnetic flux density is as small as 1/2 to 2/3 of that of ferromagnetic metals.

This invention has an object to overcome the defects of the above-described prior art that the eddy current loss becomes high in high frequency regions, and thereby provide a high magnetic permeability material having excellent high frequency properties and a high saturation magnetic flux density.

[Means for Solving the Problem]

In order to achieve the above-described object, the present invention provides a high magnetic permeability material, characterized in that a polymer deposits between ferromagnetic metal particles, the saturation magnetization is 800 G or higher, and the electrical resistivity is 180 μΩ-cm or higher.

[Working Effects]

When a ferromagnetic metal and a polymer are vapor deposited at the same time, a soft magnetic film having a large electrical resistance where a polymer deposits between ferromagnetic metal particles can be obtained.

When the two are vapor deposited in vacumm together, the ferromagnetic metal tends to have a columnar structure and the polymer deposits between columns. The polymer, which is an insulator, deposits between the columns, and therefore the electrical resistance becomes higher than in the original ferromagnetic metal. Therefore, the eddy current loss becomes smaller, and the magnetic permeability can be prevented from lowering in high frequency regions. As a result, the saturation magnetic flux density becomes high.

The high magnetic permeability material according to the present invention can be manufactured by vapor depositing a ferromagnetic metal and a polymer on the surface of a substrate at the same time. "Vapor deposition" is a method for depositing a substance or compound on a substrate as the vapor or ionized vapor in a gas or a vacuum. This method includes a vacuum vapor deposition method, an ion plating method, a high frequency ion plating method, an ion cluster beam method, an ion beam deposition method, a sputtering method and a CVD method.

In the case where the high magnetic permeability material according to the present invention is manufactured in

accordance with a vapor deposition method, it is preferable for the temperature of the substrate for vapor deposition to be kept within a range from 80°C to 220°C. When a ferromagnetic metal and a polymer are vapor deposited at the same time on the substrate while the temperature of the substrate is kept within this range, the polymer, a carbide of the metal, amorphous carbon and a silicate, or amorphous silicon, in the case where the polymer contains silicon, deposit in the grain boundaries of the ferromagnetic metal, and these form an electrically insulating layer and the electrical resistivity becomes high.

Ferromagnetic metals that can be used for the high magnetic permeability material according to the present invention are Co, Fe, Ni and other elements, and alloys of these. Alloys of such ferromagnetic metals are well known to those skilled in the art.

The polymers that can be used to form the high magnetic permeability material according to the present invention are linear or mesh polymers having a carbon number within a range of 10 to 1000, preferably 30 to 500, and more preferably 70 to 200. Specific examples of the polymer include polyethylene, polyethylene terephthalate, polypropylene, polybutene, polystyrene, polytetrafluoroethylene, polybutadiene, polycarbonate, polyamide, polyimide, polyurethane, polyvinyl chloride, polyvinyl acetate and silicone based polymers.

As for the mixture ratio of the ferromagnetic metal and polymer, generally the polymer is 5 vol% or more, desirably 10 vol% or more, and more desirably 12 vol% or more and 40 vol% or less. In the case where the polymer is less than 5 vol%, the electrical resistivity becomes less than 180 μΩ-cm. Meanwhile, when the amount of polymer exceeds 40 vol%, the ferromagnetic metal particles are too far apart, making the saturation magnetization less than 800 G and the magnetism gradually harder, which is not preferable.

The high magnetic permeability material according to the present invention can be formed on a substrate as a film. It may be scraped off from the substrate into a powder and the obtained powder can be mixed with an appropriate liquid such as a vehicle or a binder, or a appropriate solid material, for use. Thus, it is possible to manufacture molds of various forms through an arbitrary means, such as application, spraying and molding, at a desired time and place.

Accordingly, the novel high magnetic permeability material according to the present invention can be formed even on microscopic substrates in accordance with a vapor deposition method, and therefore the high magnetic permeability material can be used as a core material for micro-transformers and high-frequency inductors. In addition, the high magnetic permeability material can be used in the sublayer of magnetic recording media, such as magnetic tapes, floppy discs and magnetic discs, as well as for the core material for magnetic heads.

[Examples]

Hereinafter, the present invention is described in further detail referring to Examples.

Examples 1 and 2

The vacuum vapor deposition device shown in Fig. 1 was used to manufacture high magnetic permeability materials under the following conditions:

1. Ferromagnetic metal: iron
2. Polymer: polybutene (Example 1)
   polystyrene (Example 2)
3. Substrate: glass
4. Temperature of substrate: 150°C
5. Rate of vapor deposition: 50 Å/sec for ferromagnetic metal
   10 Å/sec for polymer

Films having a thickness of 5 μm were formed on substrates.

Examples 3 and 4

The high-frequency sputtering device in Fig. 2 was used to fabricate high magnetic permeability materials under the following conditions:

1. Ferromagnetic metal: iron
2. Polymer: polybutene (Example 3)
   polystyrene (Example 4)
3. Substrate: glass
4. Temperature of substrate: 150°C
5. Ar pressure: 10 mTorr
6. Supplied power: 1.5 kW (13.56 MHz)

Films having a thickness of 5 μm were formed on substrates.

Comparative Example 1

SiFe having a directivity of 3% was rolled to a thickness of 10 μm and annealed in a vacuum at 750°C for one hour, and thus a comparative material was obtained.

Comparative Example 2

The vacuum vapor deposition device shown in Fig. 1 was used to fabricate a FeAlSi (sendust) film under the following conditions:

1. Ingot: FeAlSi alloy ingot
2. Substrate: glass
3. Temperature of substrate: 300°C
4. Rate of vapor deposition: 50 Å/sec

Films having a thickness of 5 μm were fabricated.

Table 1 below shows the magnetic properties (saturation magnetic flux density and coercive force), the electrical resistivity and the values of the real part μ' in the complex permeability at 0.1 MHz and 25 MHz of the high magnetic permeability materials obtained in the above Examples 1 to 4 according to the present invention and the materials obtained in Comparative Examples 1 and 2. The magnetic properties were measured by a sample vibration type magnetic flux meter, the electrical resistivity was measured in accordance with a four-terminal method, and the magnetic permeability was measured using a vector impedance meter for magnetic circuits formed by pressing a ferrite core having a coil wound around it against each sample.

Table 1

Examples and Comparative Examples

Saturation magnetic flux density (T)

Coercive force (Oe)

Permeability

Resistivity

実施例および比較例	飽和磁束密度 (T)	保磁力 (Oe)	透磁率 0.1MHz	透磁率 25MHz	抵抗率 10^{-8} Ω・m
実施例1	1.5	1.5	2×10^3	1.0×10^3	180
実施例2	1.6	1.5	1.8×10^3	1.2×10^3	250
実施例3	1.4	2	1.5×10^3	1.3×10^3	400
実施例4	1.5	1.5	2×10^3	1.2×10^3	200
比較例1	2.0	1.0	7×10^2	1×10^2	60
比較例2	1.2	0.5	2×10^3	3×10^2	70

Comparative Example 1

Comparative Example 2

Example 1

Example 2

Example 3

Example 4

As is clear from the results in Table 1, the high magnetic permeability materials according to the present invention have a high electrical resistivity, and thus the magnetic permeability lowers only a little in high frequency regions, and thus the high magnetic permeability materials have excellent properties in high frequency regions.

In addition, high magnetic permeability materials using an oxide magnetic material, such as ferrite, have a saturation magnetic flux density of 0.4 T to 0.6 T, and therefore the high magnetic permeability materials according to the present invention have a greater saturation magnetic flux density than

high magnetic permeability materials using an oxide magnetic material.

[Effects of the Invention]

As described above, a magnetic material having a large electrical resistivity where a polymer deposits between ferromagnetic metal particles is used, and thus a high magnetic permeability material which deteriorates little in high frequency regions and has a high saturation magnetic flux density can be obtained.

4. Brief Description of the Drawings

Fig. 1 is a schematic diagram showing an example of a vacuum vapor deposition device used for manufacturing a high magnetic permeability material according to the present invention, and Fig. 2 is a schematic diagram showing an example of a sputtering device used for manufacturing the high magnetic permeability material according to the present invention.

Fig. 1

1 crucible for ferromagnetic metal
2 crucible for polymer
3 substrate
4 substrate holder
5 heater for heating substrate
6 vacuum tank
7 air discharging system for vacuum

Fig. 2

10 ferromagnetic metal target
12 polymer pellet
13 substrate
14 substrate holder
15 heater for heating substrate
16 high frequency power supply
17 valve
18 Ar inlet pipe
19 vacuum tank
20 air discharging system for vacuum